Exam 1 Rework

Submitted to:

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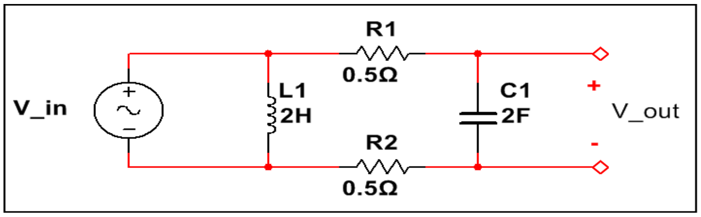
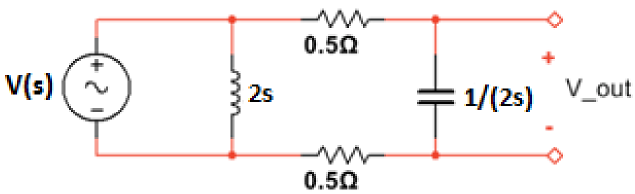
1(a). Compute the Laplace transfer function for the network shown to the right.



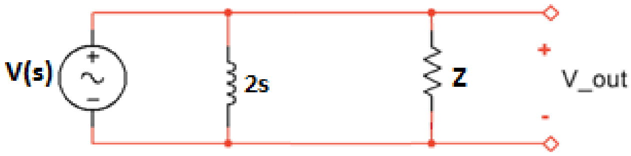
Solution

1. Compute the Laplace transform of the circuit (Assume 0 initial conditions):



The Voltage source doesn't change since were concerned with the transfer function.

2. Calculate the equivalent impedance of the outside branch:



$$Z = .5 + .5 + \frac{1}{2s} = 1 + \frac{1}{2s} = \frac{2s+1}{2s}$$

3. Calculate the current through Z:

$$I = \frac{V(s)}{\frac{2s+1}{2s}} = \frac{V(s) * 2s}{2s+1}$$

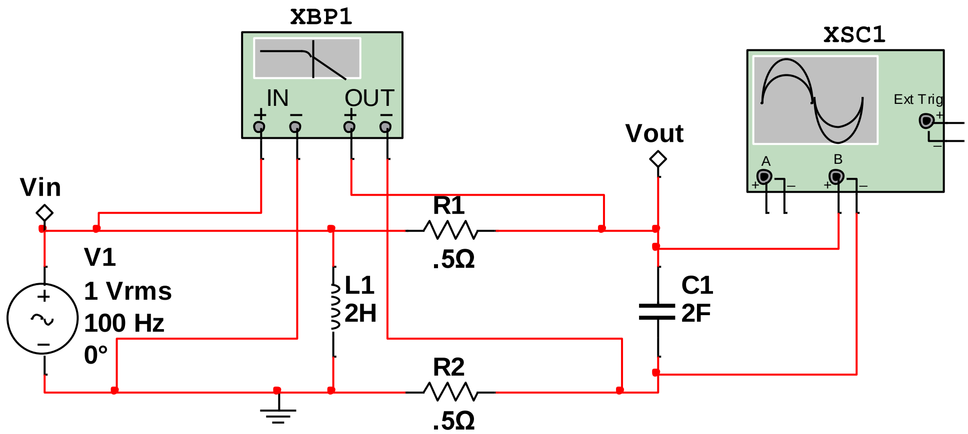
4. Find only the voltage across the capacitor in Z, using I:

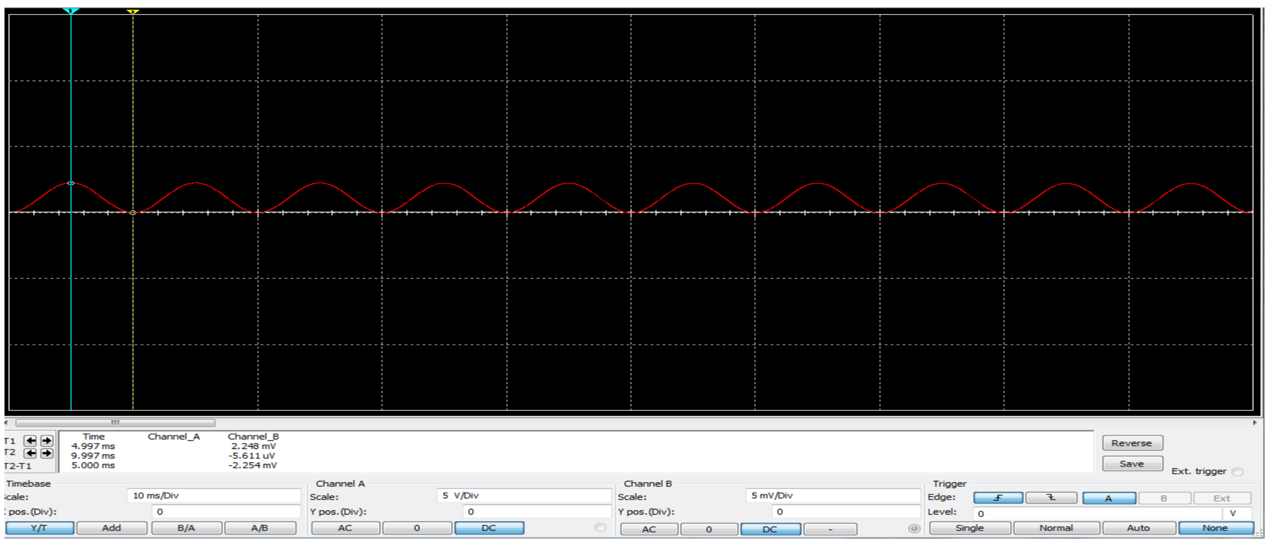
$$V_o = I * \frac{1}{2s} = \left(\frac{V(s) * 2s}{2s+1}\right)\left(\frac{1}{2s}\right) = \frac{V(s)}{2s+1}$$

5. Therefore **Vo = V(s) / (2s+1)**, now divide through by V(s) to get the transfer function:

$$\boldsymbol{H(s)} = \frac{Vo}{V(s)} = \frac{1}{2s+1}$$

Multisim





Calculations

1. I chose a Voltage source of 1Vrms with a 100 Hz frequency. Giving my output voltage the value:

$$Vo = 1\left(\frac{1}{\sqrt{16\pi^2(100^2)+1}}\right) = .00079577V$$

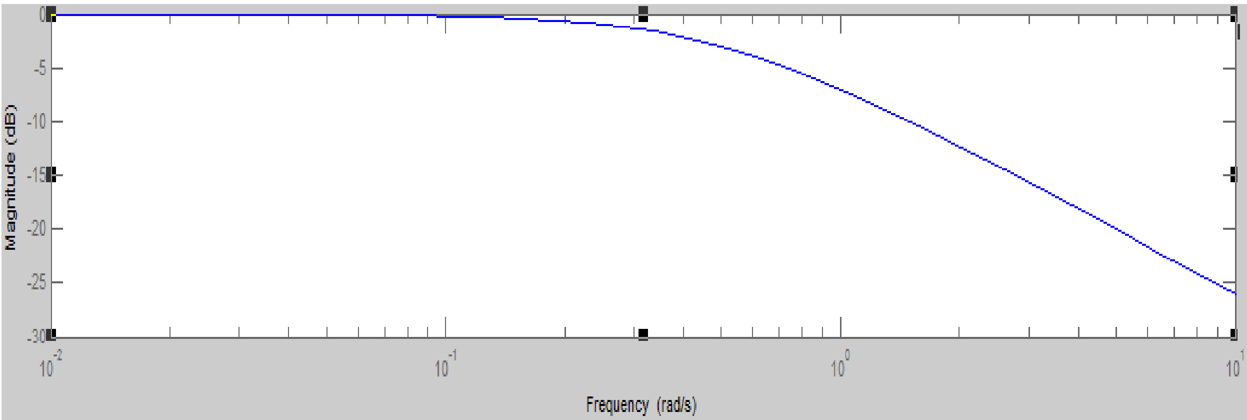
2. The measured output voltage found in Multisim is:

$$Vo = \left(\frac{2.253mV}{2\sqrt{2}}\right) = .0007966V$$

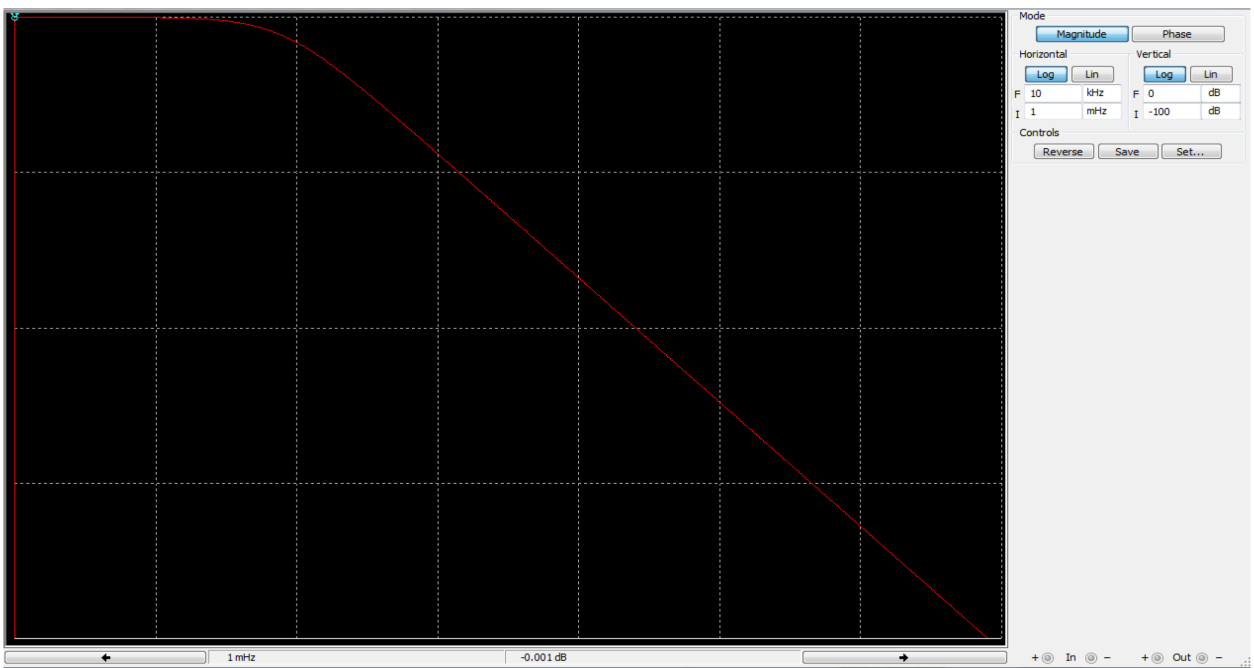
3. By comparing Multisim results to my Theoretical output voltage, I notice that the two are in fact quite similar. The percent error being 5.13%

1(b). Sketch the Bode plot (log magnitude as a function of log frequency). You can use MATLAB for this. However, either way, explain why this plot makes sense. An explanation is required to get maximum credit.

<u>Matlab</u>



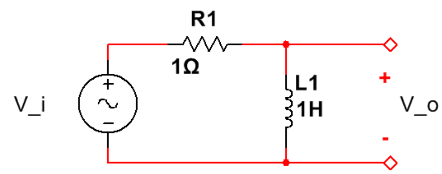
<u>Multisim</u>



<u>Explanation</u>

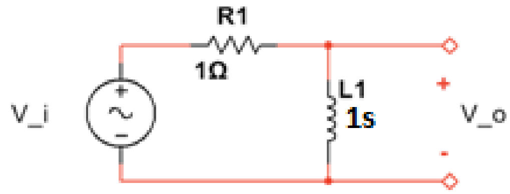
This plot makes sense, because the transfer function **H(s) = 1/(2s+1)** is first order. Which means it is either expected to have exponential growth or decay, in this case decay. Also, by replacing *s* with *jw* you notice that as frequency grows large, H(s) goes to zero which is what we see happening in the graph.

2. Consider the circuit shown to the right.Compute the output voltage, $v_o(t)$ assuming $v_i(t) = u(t-1)-u(t-2)$. (Hint: sketch $v_i(t)$.)



Solution

1. Calculate the Laplace transform of the circuit (Assume zero initial conditions):



V_i doesn't change because we're concerned with the transfer function.

2. The voltage across the inductor is then simply the voltage divider between it and the resistor:

$$V\_o = V\_i\left(\frac{s}{1+s}\right)$$

3. Compute the Laplace transform of V_i using Matlab using the heaviside command for u(t):

\Matlab >> laplace(heaviside(t - 1)) - laplace(heaviside(t - 2))

$$V\_i(s) = \frac{e^{-s}}{s} - \frac{e^{-2s}}{s}$$

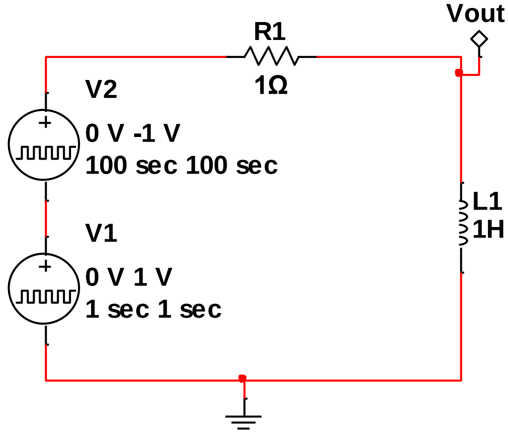
4. Therefore: $$V\_o_{(s)} = \left(\frac{e^{-s}}{s} - \frac{e^{-2s}}{s}\right)\left(\frac{s}{1+s}\right) = \frac{e^{-s}}{1+s} - \frac{e^{-2s}}{1+s}$$

5. Using Matlab, take the inverse Laplace transform of V_o, to get it back into the time domain.

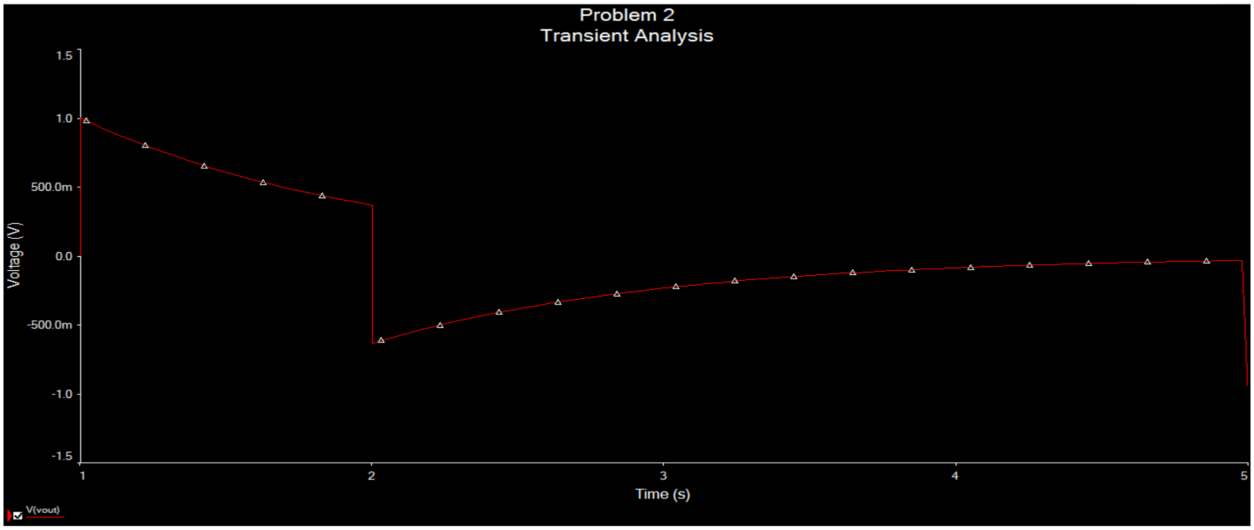
\Matlab >> ilaplace((exp(-s)/(1+s)) - (exp(-2s)/(1+s)))

$$V_{o(t)} = u(t-1) * e^{(1-t)} - u(t-2) * e^{(2-t)}$$

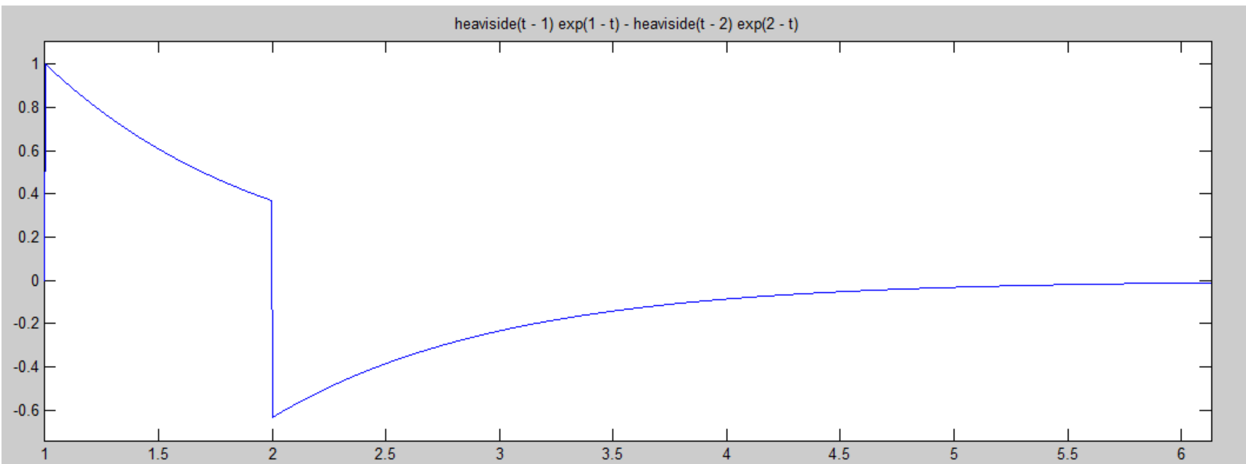
Multisim



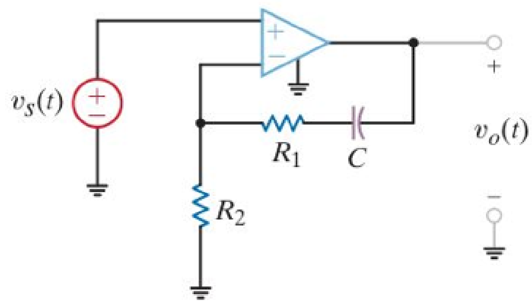
Transient Analysis (Multisim)



Transient Analysis (Matlab)

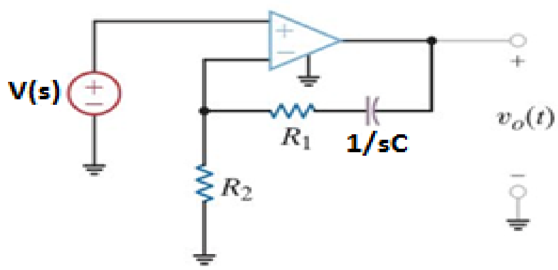


3.Compute the Laplace transfer function of the circuit shown to the right. If you can't derive the expression, tell me as much as possible about the transfer function in a qualitative sense.



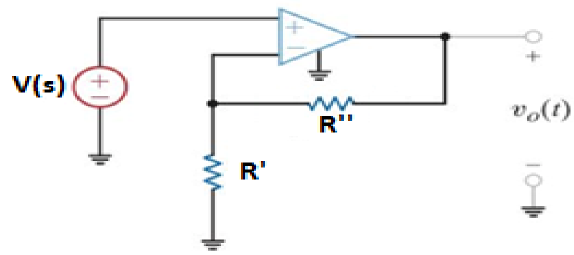
Solution

1. Compute the Laplace transform of this circuit (Assume zero initial conditions):



2. From characteristics of op-amps: $\frac{Vo}{V(s)}$= Gain

3. Calculate R' and R'' in the circuit below:



R' = R2

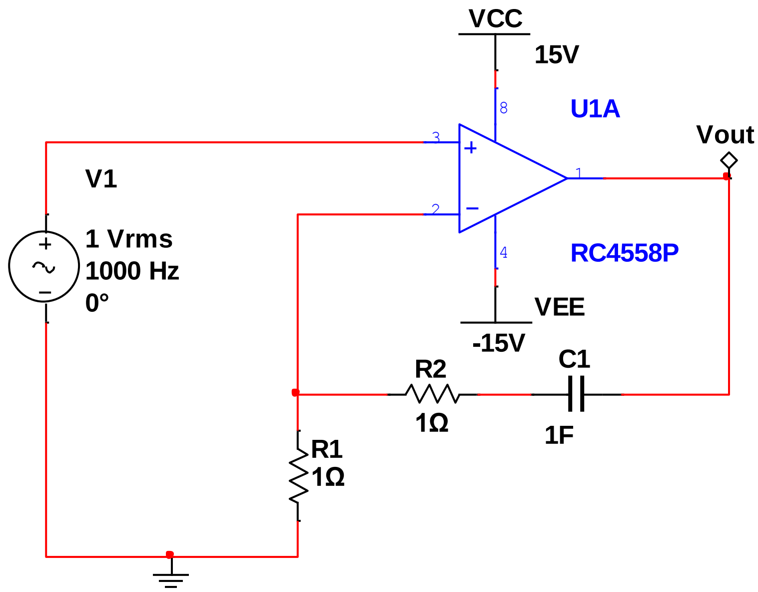
R'' $= \boldsymbol{R1} + \frac{\mathbf{1}}{\boldsymbol{sC}} = \frac{\boldsymbol{R1*sC+1}}{\boldsymbol{sC}}$

4. For Non-Inverting op-amp:

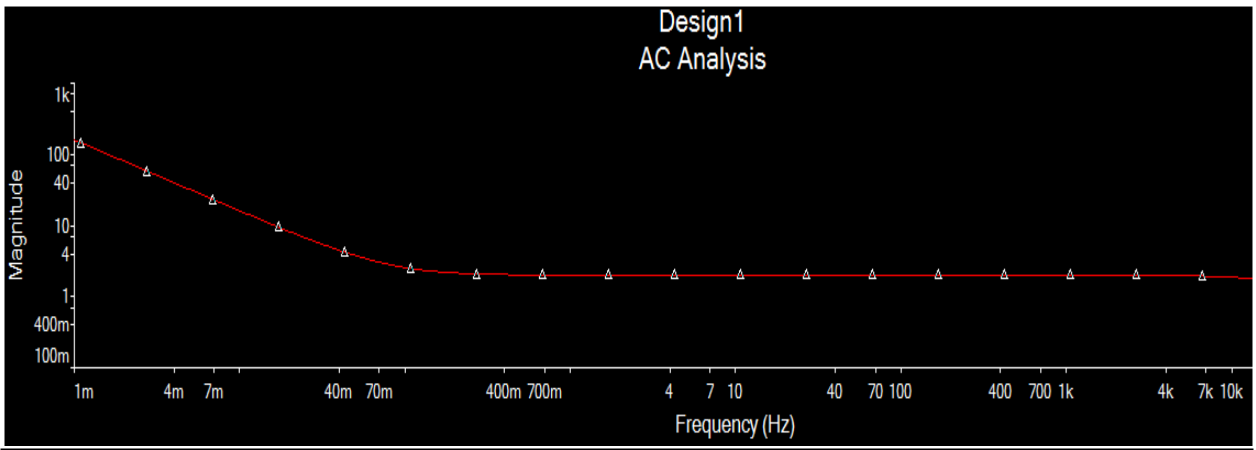
$$\text{Gain} = 1 + \frac{R''}{R'} = 1 + \frac{R1+\frac{1}{sC}}{R2} = 1 + \frac{R1}{R2} + \frac{1}{R2*sC}$$

5. Therefore: **H(s)** $= \frac{\boldsymbol{Vo}}{\boldsymbol{V(s)}} = 1 + \frac{R1}{R2} + \frac{1}{R2*sC}$

Multisim



AC Analysis



Explanation

This plot makes sense, because we notice from the transfer function that:

$$\mathbf{H(s)} = 1 + \frac{R1}{R2} + \frac{1}{R2 * sC} \quad \text{,which means:} \quad \text{Gain} = \frac{Vo}{V(s)} = 1 + \frac{R1}{R2} + \frac{1}{R2 * sC}$$

Notice that as the values of frequency are very small, the $\frac{1}{R2*sC}$ term is very large giving the op-amp a large gain term. Similarly, as frequency goes to infinity, the $\frac{1}{R2*sC}$ term goes to zero, leaving us with:

$$\frac{Vo}{V(s)} = 1 + \frac{R1}{R2} \quad \text{From the circuit above:} \quad \frac{R1}{R2} = \frac{1}{1} = 1 \quad \text{Therefore:} \quad \frac{Vo}{V(s)} = 2$$

Which is what the circuit levels out to after a certain value of frequency is achieved.